BENGAL SECRETARIAT

REPORT OF A VISIT

TO THE

TORRENT REGIONS OF THE HAUTES AND BASSES ALPES,

AND ALSO TO

MOUNT FARON, TOULON.

BY

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CHAPTER I.

General account of the Torrent Regions, and of the works undertaken in them.

Introduction.

After a few days spent at the Nancy Forest School in examining the plans, models, photographic views, &c., exhibited at the late Paris Exhibition in connection with the *reboisement* of mountains and the treatment of torrent and denuded areas, I proceeded to Digne in the Basses Alpes, to the officers in charge of the works at which place I had been provided with letters through the kindness of M. Nanquette, Director of the Forest School. I found that no works of particular interest were in progress in this neighbourhood, bu I obtained much valuable information from the Forest Officers, and I then proceeded to the upper portions of the Basses and Hautes Alpes, where the effect of torrents and their treatment can be more advantageously studied.

Geological formation.

2. In this part of France the rock is chiefly limestone and soft schist, the lower slopes of the hills being covered with extensive beds of very friable black marl. There is also a considerable quantity of nummulitic limestone and of soft sandstone.

General character of the hills.

3. The hills here attain an elevation of from 7,000 to 10,000 feet, with deep valleys between them, and especially where they have been denuded by the destruction of the forests they form a mass of a crumbling and most unstable nature. The slopes of the hills are steep, and even precipitous in many places, and, as the valleys are short, it naturally follows that the rain runs off with great rapidity. This is especially the case where the hills have been deprived of the protection of the forests, the effect of which—it has now been pretty clearly established—is to retain, for a time at least, one-third of the water precipitated on a given surface.

Forest vegetation.

4. The natural forest vegetation of this region is composed principally of Scotch fir on the lower hills, with spruce, silver fir, larch, and a few *pin à crochets* on the higher peaks. From the lower slopes the forest has almost disappeared, except where a few patches of Scotch fir, generally situated in the most inaccessible places and at considerable distances from the villages, indicate that probably the unstable hill sides were covered with a dense forest growth at no very distant date. With the exception of the scattered fir trees, there is hardly a vestige of vegetation left, the few stunted bushes that remain being eaten into small hard knobs by the still numerous flocks. These bushes must, of course, finally succumb in the unequal struggle, when the slopes will remain completely barren. The higher portions of the hills above the black marl are sometimes well wooded, and some fine forests of larch and spruce still exist; but here the effect of the removal of the forest has not been so disastrous as on

the lower slopes, because the rocks towards the summits of the hills are harder than those found lower down. The tops of the hills above the region of the forests are used as grazing grounds. On account of their great elevation they have probably never been completely covered with forest, except perhaps at some very remote period, when the climate of Europe may have been much hotter than it is now; and they are now generally covered with thick turf.

Causes of denudation

5. Most of these hills belong to the neighbouring *communes*, or village communities; and, as it is probable that there never was much culturable land, the inhabitants took to keeping large flocks of sheep and goats, which became more numerous as the population increased during the last century. It is asserted that before this time all the mountain ranges of the south of France were thickly covered with forest, and that floods occurred after much greater intervals and with a much less destructive effect than at present. The increase of the flocks naturally led to the rapid destruction of the forest on the lower slopes, and it is said that the upper line of the forest has been considerably lowered. This is due to the fact that the flocks are generally driven up to the higher pastures for the four or five summer months, and it has, of course, been to the interest of the shepherds in charge to burn and destroy the forests in the higher regions as much as possible in order to gain more extensive grazing grounds. The destruction of the forests thus proceeds in exactly the same manner as it does in some parts of the Himalayas at the present time. But it is not the ravages caused by the local flocks alone which have led to so much destruction, for it appears that immense herds of goats and sheep are driven up annually from the lower parts of Provence to graze in the higher pastures during the summer months, grazing dues being levied from their owners by the neighbouring *communes*. It is, however, said that these migratory flocks are not nearly so destructive as the local ones, for the former arrive late in the spring and depart early in the autumn, when the vegetation is in full vigour; whereas the local flocks overrun the mountains all the year round, at different levels, according to the season, and they are constantly grazing down every blade of vegetation, while, especially after the snow melts in the early spring and during the late rains of autumn, the friable soil is loosened by their feet.

The opening up of the country by roads, and the construction of saw-mills, has also probably led to a considerable export of timber from these regions during the last century. All these circumstances, added to a climate and soil unfavourable to forest vegetation, have led to the gradual destruction of the forests.

Climate

6. The climate of the upper portions of the Hautes and Basses Alpes presents greater extremes of temperature than are perhaps found in any other part of France. The winters are long, and snow sometimes covers a considerable portion of the mountains for more than half the year. The change of the season takes place very suddenly. The snow melts quickly, and what may be called a Russian winter is rapidly transformed into an Algerian summer. During the hot season long droughts are frequent, and they are often succeeded by tempests of wind accompanied by sudden deluges of almost tropical rain, which, falling on the steep and denuded hill sides, gives rise to sudden floods, and to the destructive mud torrents, of which so much has of late years been heard. It frequently happens that a considerable period elapses without any destructive effect being caused by the mountain streams, when suddenly a series of storms, such as those which occurred in August 1876, awakens them into activity, the results, which are sometimes felt far down the valleys, being most disastrous to the cultivated lands and roads situated in the vicinity.

During the periods of repose immense quantities of materials on the denuded hills have, of course, become loosened by heat, frost, and various other causes, not the least important of which is the action of the sharp hoofs of the numerous flocks which are continually overrunning them, so that when a sudden tempest occurs the rain at once sets in motion a miscellaneous mass composed of black mud, gravel, and boulders, some of which are not unfrequently several tons in weight. If the rain continues long enough these moving masses, called *laves*, are followed by floods of water, which rush into the main river and cause it to rise suddenly with disastrous results. The accompanying sketches (Figs. 1 and 2, Plate I.), showing sections of the *laves*, will help to explain their nature.

7. The roads are everywhere found to traverse the beds of *débris* (called *lit* or *cône de déjection*) of the torrents. These deposits stretch out in immense fan-shaped beds of boulders, gravel, and black mud; some of them, such as those of the Rion-Bourdoux torrent, near Barcelonnette, and of Boscodon, 4 miles below Embrun, cover, in beds of from one to 3 miles in breadth, areas of 400 or 500 acres of good land. All these deposits are high in the centre and slope down towards the sides, the bed of the Boscodon torrent, at the place where the road passes it, being at least 50 feet higher in the middle than at the sides. Considerable difficulty is sometimes experienced in passing over the deposits, notably near Barcelonnette, where the national road, in the course of about 3 miles, traverses 5 or 6 *lits de déjection*; here, as long as the torrents from the neighbouring hills continue their destructive effects, it will always be liable to be swept away and rendered impracticable after a storm. The villages seem small, and some of them are apparently in a dilapidated condition. This is probably due to the migration of the inhabitants to more favoured regions as their patches of cultivation are gradually destroyed by the action of the mountain torrents, and as the hills, having become denuded of vegetation, become unable any longer to support the ever-increasing flocks. General appearance of the regions affected by the torrents

8. The general resemblance of the country to certain parts of India is very noticeable. The lower portions resemble, to a great extent, the dry hilly parts of Rajputàna and the Salt Range of the Punjab, while the higher parts have somewhat the appearance of the hills and valleys of the Himalayan mountains. In the lower portions are to be seen the same barren sterile hills, generally denuded of all vegetation, cut up by numerous deep ravines, and presenting a most unpromising appearance, while in the higher parts the same steep hills and deep intermediate valleys, dotted over with small hamlets and diminutive patches of cultivation, are met with. Another striking resemblance between this region and the drier portions of India is that, where water is available, irrigation is extensively resorted to, and there are many important irrigation canals; consequently a regular supply of water in the form of springs is, especially during the summer months, highly important, and it has now been satisfactorily established that well-wooded catchment basins alone can ensure this. Resemblance to certain parts of India

9. The destruction worked by the mountain torrents has been graphically described by M. Surell and other authors. In the Department of the Basse Alpes alone an area of about 15,000 acres of valuable land has been rendered unproductive by them. This area might be brought under cultivation but for the uncertain and shifting nature of the course of the Durance and its numerous tributaries, due to the immense quantities of soil and rock brought down by the torrents. However, after these torrents have been somewhat controlled, the construction of dykes and other works will be possible, and an area now quite unproductive may be rendered available for cultivation, when it will be worth from 30 to 36 millions of francs. The damage done in the south of France by the floods of June 1875 has been estimated at £3,000,000. It is probable that the damage caused by some of the Indian torrents, such as the Bhimbar, Sohan, Haro, and others in the Panjab, is equally as great as that above described; and if the Salt Range, the soil of which very much resembles that of the marl hills of the Hautes and Basses Alpes, was subject to the sudden and violent tempests which are experienced in the region treated of in this report, mud torrents would probably be formed with the same disastrous results. Damage by torrents.

10. There has been much delay in dealing with the question of conserving and reforesting the bare hill ranges of the south, the denudation of which has long been known to be the primary cause of the many disastrous floods which have occurred, especially during the present century. This delay may be attributed partly to the fact that the French Forest Administration has only realized, within the last ten or fifteen years, that the *reboisement* of the arid hills can actually be accomplished, and this after many experiments and many failures. Even at the present advanced stage of Forest Science in France, some uncertainty seems to exist regarding the best methods of procedure in certain difficult cases. It is only by actual experiment that such questions can be finally settled, and, as, in elevated and exposed positions, forest vegetation is of very slow growth, it is only after the lapse of a much longer period than has yet passed that actual results can be made available for future guidance. The principal cause of delay, however, was that in these districts the State possessed Causes of delay in dealing with the torrents.

very limited areas, the greater portion of the hill ranges being the property of the neighbouring *communes* or of private proprietors, by whom all attempts at legislation were sternly opposed. They were, of course, thoroughly alive to the fact that any new forest enactment meant restriction of their grazing rights, which they clung to tenaciously, even after the grazing grounds had been rendered sterile, and had thus become quite unfit to support half the flocks which annually wandered over them.

Legislation effected.

11. After the great inundations of 1856, however, the French Government determined to legislate in this important matter, and, notwithstanding all the objections raised to it, a Bill was at last passed, which is known as the law of 1860. The principal object of this law is to encourage and aid *communes* and private proprietors to effect the *reboisement* of their denuded lands themselves; but it also provides that in the more urgent cases communal lands may be brought under the forest *régime*, and that private proprietors may, when necessary, be expropriated. The application of this law met with the most violent opposition, and some modifications of it were sanctioned by the law of 1864, which permits the *gazonnement* (turfing or sowing with grasses) of certain portions of the hill sides in lieu of planting operations.

Neither of these laws has, however, been found to be effective, as they do not sufficiently control the extensive areas which are the property of private individuals, and as attempts to encourage private enterprise have, as a general rule, proved futile, a new Bill has been brought before the Senate, the object of which is to submit to the forest *régime* all property, whether private or communal, the denudation of which is considered to affect the general welfare of this region by its influence on the destructive floods and torrents.

Engineering works

12. Attempts have often been made in former years to regulate the courses of some of the torrents by means of strong and expensive embankments, which were raised higher and higher in proportion as more material was brought down and deposited by the streams; but in most cases these efforts have proved ineffective, and in the worst cases steps have now been taken to attack the evil and its source by effecting the *reboisement* of the hills and the filtering of the streams by means of a series of wooden and stone weirs. The object of these works is to prevent, as much as possible, the further erosion of the soil from the bottoms of the ravines, and to filter the rushing water so as to free it from the earth, gravel, and boulders, which, when they are carried along with it, cause so much destruction. As a general rule, in the tracts I visited, the storage for purposes of irrigation of the water retained by these weirs does not enter into the question of their construction. The system now adopted is the result of numerous experiments conducted by the French Forest Department, and a brief account of them will be given. The works which play the most important part in the success of all *reboisement* operations are,—

1st.—Fascinages (willow fascines and stakes).
2nd.—Clayonnages (stakes with willow wattlings).
3rd.—Barrages (masonry weirs).

Fascinages

13. *Fascinages* can only be employed at the heads of ravines and inside valleys, where the flow of water is very small. They are divided into two classes—those of the first class being from 2½ to 5 feet in height with a length of from 20 to 26 feet, and those of the second class being of any size below the above limits.

Fascinages of the 1st class are thus formed: Rows of posts, generally of willow or some other species which takes root easily, are firmly driven into the ground about a yard apart. Behind the posts are placed fascines which consist of branches of trees bound together into bundles of about 40 inches in circumference and made long enough to extend across the bottom of the ravine. The branches used are, generally speaking, from the willow tree, but when these are scarce, the interior of the fascine may consist of any other kind of branches or bushes that may be available. After the posts have been driven in, and the ground behind them levelled, a line of willow or alder cuttings is laid on the ground and covered with earth; behind them a rough flooring is laid with flat stones to prevent the water from undermining the structure; above this flooring and the cuttings, the first fascine is placed and firmly bound to the posts by means of willow twigs. Above the fascine a second row of cut-

tings is laid and backed up with earth, and then another fascine is placed, and so on until the required height is obtained, the ends of the fascines being firmly embedded in the banks and the top of the structure having a slightly concave form. The number of fascines required for *fascinages* of the 1st class rarely exceeds three, but sometimes as many as five are necessary. Earth, or whatever material may be available, is then thrown behind the *fascinage*, which is then complete. The cuttings and the posts are intended to form in the course of a few years a living barrier across the ravine, but it is found in practice that the posts rarely take root except when the ground is very damp. The accompanying diagram of a *fascinage* of the 1st class will help to explain what is meant (Fig. 3, Plate I). *Fascinages* of the 2nd class have only one or two rows of fascines, and they are constructed and used in exactly the same manner as those above described. Sometimes, however, the posts, instead of being placed before the fascines, are driven through them. The cost of *fascinages* of the 1st class varies from 20 to 30 francs, and of the 2nd class from 5 to 10 francs. The distance apart at which *fascinages* are constructed depends on the nature of the ground and the slope; as a general rule, they are from 4 to 6 yards apart, but in some cases, when the fall of the ground is very rapid, they are placed at distances of only 7 to 10 feet apart, and they then form a kind of stair. Small *fascinages* of the 2nd class are often constructed in rows, one above the other, along the face of unstable banks, the slopes of which are too steep to allow of any method of planting or sowing being employed.

Clayonnages

14. *Clayonnages* are of a much more complicated nature than *fascinages*, but, like them, they are intended to oppose a living obstruction to the materials brought down by the mountain torrents. These works are generally used in small valleys, but in some cases, especially where stones are difficult to obtain, they are constructed in ravines of considerable size. They are divided into two classes, those of the 1st class being sometimes from 20 to 30 yards long, the height rarely exceeding 5 feet. A line of strong piles, the lower ends of which have been first carbonized, are driven into the ground about a yard apart; the piles are usually of larch, but if they are of willow they are placed at half a yard apart: a short distance below the surface of the ground a wattle of strong willow branches is commenced and is carried up to the required height. Above the willow wattle, strong beams, which are firmly nailed to the upright piles, are placed; the ends of these are embedded in the sides of the ravine, extra props, tie rods, &c., being sometimes used to strengthen the structure. The central portion, for a distance of from 3 to 7 yards, is made horizontal, but the extremities are sloped upwards towards the sides of the valley at an angle of about 20°. The whole face of the *clayonnage*, from top to bottom, is thickly planted with willow and alder cuttings, as well as with ash plants, the heads of the cuttings and plants being left protruding between the willow wattles, and the back of the structure is filled up with earth and stones, so as to form a strong barrier against the first shock of the rocks brought down by the torrent. When any considerable flow of water is expected in the ravine, a second and smaller *clayonnage* is generally constructed immediately below the first, the intervening space being usually paved with large flat stones. These smaller barriers, which are about $1\frac{1}{2}$ feet in height, are called *radiers*. The accompanying diagram (Fig 4, Plate I) represents a *clayonnage* of the 1st class. The cost of such a work varies from 100 to 170 francs.

Clayonnages of the 2nd class are generally employed at the heads of ravines, or between clayonnages of the 1st class, with the object of reducing the fall of the ravine to one general slope. As their dimensions are much less than those of the 1st class, their construction is not nearly so complicated, and the cost of construction is from 12 to 50 francs only.

The sides of the ravines are often protected from erosion by means of hurdles of wattles and stakes called longitudinal *clayonnages* (*clayonnages longitudinaux*), in which numerous willow cuttings are planted. In order to protect them as much as possible, and to allow a free passage for the water, the larger stones are collected from the centre of the torrent bed and placed at the foot of the hurdles.

Barrages.

15. A *barrage* is a much more elaborate and complicated work than either of those just described, and as some of them cost as much as 130,000

francs each, careful surveys, plans, and estimates must be prepared before they are undertaken. As weirs of this description are constructed in the lower gorges of the most important ravines, where there is often a considerable flow of water, they must, of necessity, be very solid and substantial.

They are divided into three classes,—

1st.—Those constructed of solid masonry with hydraulic lime.

2nd.—Those constructed partly with lime and partly of rubble masonry.

3rd.—*Barrages rustiques* (rustic weirs) constructed entirely of dry stone masonry.

Several types of the first kind of weir are employed, some with their outer faces nearly straight, while others are very much curved. The upper surface is also sometimes curved, but it is sometimes nearly horizontal. Wing walls are generally added both up and down stream. The length of the embankment is, of course, regulated by the breadth of the ravine in which it is constructed. Some of the weirs visited had lengths varying from 30 to 80 yards, the height above the surface of the ground being from 17 to 20 feet, while the foundations are sunk to a similar depth, and the breadth being proportionate to the height. The foundations are generally laid on rock, and dressed stones with the best hydraulic cement are used throughout, the blocks of stone on the upper surface of the weir being usually bound together with iron clasps. All *barrages* of the 1st and 2nd classes are constructed with a large central culvert which has a grating of strong posts, the object being to allow the water and mud brought down by the torrent to pass through the weir, and thus to leave more room behind it for the deposit of the larger masses of rock, &c. If the main weir is of great height, and the amount of materials brought down by the stream is large, it is necessary to place below it a solid floor of large stones, supported by a second and smaller weir called *contre-barrage* or *radier*. The accompanying sketch of a *barrage* (Fig. 5, Plate II) will help to explain its nature, but the construction admits of so many variations and is so complicated that any description in a short report must necessarily be very defective. The cost of construction may be put down at from 20,000 to 130,000 francs. When the action of the torrent is not very violent the expense of construction may be reduced by building the weir of rubble, faced with masonry set in mortar. Such weirs are called 2nd class *barrages*, and they are not usually more than from 15 to 20 yards in length and from 15 to 35 feet in height including foundations. The cost may be estimated at from 5,000 to 20,000 francs. In smaller ravines, and in places where the torrent has not much force, rustic weirs are usually constructed. These are built entirely of rubble and without a culvert. These cost from 300 to 3,000 francs only, but they are not so good as the more expensive kind, because the space behind these sooner becomes filled up. They are, however, useful when, on account of the rocky nature of the ground, *clayonnages* cannot be constructed, or when the excessive cost of the carriage of lime renders it impossible to build more permanent works. These weirs run from 5 to 12 yards in length, and from 7 to 14 feet in height, including foundations. Fig. 6, Plate II represents one of these works.

The distances at which these weirs are placed apart depends on the slope of the ravine, one of the objects in view being to reduce the slope of the ravine bed to as nearly one in ten as possible. This can usually be managed by placing the large *barrages* at distances not less than 100 to 150 yards apart, the intervening space being crossed at regular distances by *radiers*, *clayonnages* and other small weirs; but rustic weirs are sometimes constructed only a few yards from one another, so that whole ravines for several hundreds of yards sometimes present the appearance of huge flights of steps.

Effect of these works

16. The immediate effect of all these works is to prevent the further deepening or scouring out of the ravine beds, and the consequent rolling down of the adjoining banks, and when this effect is produced, planting and sowing operations can be undertaken with some chance of success. The direct effect on the *lit* or *cône de déjection* is that, as no more materials are brought down, the clear water begins to hollow out a well-defined course with regular banks, instead of running all over it, spreading destruction and frustrating all attempts at reclamation.

17. M. Surell, in his well known treatise on the treatment of torrents, lays down as a general principle that the works should always be commenced at the sources of the torrents, but it is found in practice that this theory cannot always be carried out for the following reasons:— Order in which works at different level should be undertaken.

1st.—In the case of great differences of altitude between the highest and lowest parts of a tract, such as that of Seyne, which will be described later on, operations can, on account of the early fall and late melting of the snow and of the great heat and drought of the summer months, only be carried on in the upper portions for a few weeks at the end of the spring and at the beginning of autumn. By confining operations to the upper portions, much valuable time would, therefore, be lost which might be employed on works at a lower level.

2nd.—In order to prevent the sliding down and washing away of the slopes, which would render all plantation and sowing works impossible, it is in some cases advisable to commence the construction of a series of weirs low down in the gorges, and to work upwards as they become filled up.

3rd.—As it is of the highest importance in works of this nature to employ skilled labour and to retain the workmen in the neighbourhood, it is advisable to employ them throughout the working season, and thus to prevent them going elsewhere, which they would do, at all events during the first years, if operations had to be confined to the sources of the streams only. In fact, the work must be so conducted and timed as to fully employ all available labour, and at the same time to interfere as little as possible with the agricultural arrangements of the country. This can only be effected by undertaking work at different elevations in the area under treatment.

18. As regards the cost of the *reboisement* operations, which in some cases has already reached the excessive amount of 350 francs per acre for works still incomplete, it must be remembered that they are being prosecuted without much regard to expense; but the officers in charge explain that large sums have been expended on experiments which have often turned out failures. This was, of course, unavoidable. Cost of the reboisement works.

CHAPTER II.

Descriptive account of the tracts visited.

19. I shall now proceed to describe the different operations pointed out to me by the officers in charge of the forest, my best thanks being due to them for the pains they took to explain them to me.

Périmètre of Curusguet.*

20. The first tract visited was that of Curusguet, situated about 7 miles from Digne, in the Basses Alpes, on the road to Seyne. The area under treatment is 1,042 acres, the whole of which belongs to the neighbouring *communes*. It consists of a series of low hills and valleys, the rock being limestone and soft schist, with extensive beds of black marl. General description.

21. Over a considerable area, especially in the neighbourhood of the road, the planting has been completed, it being a general rule to commence operations where the results will be seen best. The trees planted are ash, poplar, acacia (*Robinia*), maple, and elm, some of the transplants being at least 7 feet in height. The higher portions and worst descriptions of land were being planted with two-year-old plants of Austrian pine, each plant being surrounded with three or four large stones, which are said to have a wonderful effect in protecting the plants from the sun, and from being uprooted by the action of the frost, as well as in retaining moisture during the droughts of summer. The remainder of the area is only being protected at present, as the extent of the *reboisement* operations is, of course, limited by the budget grants, and time is Cultural operations.

* Tract submitted to the forest *régime* with the object of effecting its *reboisement*.

thus afforded for the over-browsed grass, herbs, and bushes to recover themselves to a certain extent, and thus to form a vegetable covering before planting or sowing operations are actually commenced. The power of the natural vegetation to re-clothe naked hillsides seems to be far less in the Alps than in some of even the drier parts of India. In some cases the method of pruning down close to the ground (*recépage*) the remains of all bushes and other natural growth is resorted to, as the fresh shoots are then found to make much more rapid progress than if the often-browsed bushes were allowed to sprout naturally. The whole area forms the catchment basin of an important branch of the Bleone River, and as the hills have been reduced to a state of complete barrenness and thus ruined for grazing purposes, their *reboisement* has been decided upon. As the tract was only taken up a few years ago, and operations have only recently been commenced, the results are not yet very apparent. However, a good commencement has been made, and planting and other operations were in active progress at the time of my visit.

Construction of weirs and fencing.

22. As a preliminary measure, in order to facilitate the construction of weirs, a series of narrow paths has been constructed, following roughly the contour lines round the sides of the valleys. By means of these paths the movements of the workmen, and the carriage of tools and plants are greatly expedited. Gangs of workmen were engaged on the construction of *fascinages*, *clayonnages*, and rustic weirs in several of the side valleys. Some gangs of workmen wer also engaged in the operation known as slope-cresting (*encrêtement or talutage des berges*), which consists in rounding off the crests of the spurs on each side of the ravines under treatment: the débris, which, of course, consists only of loose material capable of being removed with the spade, being thrown down behind the *fascinages* so as to reduce the angle of the slope, and thus to render the ground more suitable for maintaining vegetation, while at the same time, the ravine is filled up to some extent, and suitable sites are furnished for planting. The great objection to this system is its cost, and it is only resorted to when the crests and slopes are formed of soft marl, for if hard material is encountered the cost becomes enormous and out of all proportion to the advantages to be gained, and this method can, therefore, only be adopted in exceptional cases. Some photographic views seen at the Forest School represent this operation graphically.

Very little fencing has been done in this tract, cases of cattle-trespass being rare. This is due to the law-abiding character of the villagers and to the care exercised by trustworthy forest guards.

Similar works on private lands

23. A little further on the same road, two villages, named La Javie and Beanjur, were passed, where certain small areas of a few acres each have been set aside and planted by the villagers with the assistance and advice of the Forest Department. Many of the ravines have been treated by means of small but skilfully constructed *barrages*, *clayonnages*, and *fascinages*, and the greater portion of the areas set aside have been planted up with Austrian pine, the young plantations being now in a most flourishing condition.

Périmètre of Labouret.

General description.

24. The *périmètre* of Labouret is situated about midway between Digne and Seyne, and is highly interesting on account of the great success which has attended the *reboisement* operations, which are now nearly completed. The area of this tract is 288 acres. It is said that before operations were commenced, about 17 years ago, there was hardly a vestige of vegetation on its surface, the soil consisting of loose black marl of the most unstable and barren nature, which was liable to be washed away by every shower of rain.

Cultural operations.

25. The natural vegetation seems to have consisted chiefly of Scotch fir, which would in ordinary cases indicate that this species ought now to be planted; but experience has shown that Austrian pine is much more easily cultivated and grows much more rapidly than the Scotch fir, which is well known to prefer a sandy soil. When operations were at first commenced, plantations of various kinds of trees, such as oak, chestnut, and lime, were made; but these species have generally been found unsuitable to the black marl soil, and more hardy trees, such as poplar, ash, acacia (*Robinia*), and elm, some of which are at present 40 feet high, are now planted in the valleys

and on the sides of the ravines, while the Austrian pine is almost exclusively planted near the ridges.

In order to retain the unstable soil in certain bare places, and thus to prepare the way for forest vegetation, extensive sowings of *Sainfoin* and *Fenasse* (trefoil and a kind of rye-grass) have been made. These plants have a very rapid growth, and are found to be very effective in temporarily fixing the soil; but they die out rapidly, and unless replaced by the naturally-grown grasses, they have to be renewed from time to time.

Construction of weirs.

26. The whole tract is intersected with innumerable small ravines, which have all been treated in the most skilful manner by means of the usual works, which, in combination with planting operations, have had the effect of reducing a once dangerous torrent to an inoffensive stream. Two large photographs among the collection at the Forest School at Nancy represent in a most striking manner portions of this tract before operations were commenced and after they had been planted up. In the lower portion of the main ravine, ten or twelve small weirs have been constructed at distances varying from 50 to 100 yards apart, the intermediate spaces being crossed by innumerable *clayonnages, radiers, &c.*, while the sides of the ravine have been supported by means of longitudinal *clayonnages*. It is difficult to determine the proper positions for the *fascinages* and *clayonnages* until some time after the main weirs have been constructed, so that the erection of these works is not even yet completed, and after they have been constructed they require constant repair. Opposite No. 12 *barrage* I observed a considerable extent of black marl hill, which, owing to its very unstable nature, has not yet been successfully treated. Various methods have been tried, but without success, owing to the extremely rapid slope; and now the surface is being gradually consolidated by rows of fascines, but these have in some cases been carried down by the friable and extremely unstable soil. Above this point in the main ravine, about fifteen or twenty rustic weirs and *clayonnages* have been constructed, while numerous works of a less important nature have been erected in the side valleys. This being one of the first tracts in which these operations have been conducted in a regular manner many failures were encountered, *clayonnages* especially having, through want of experience, been constructad in the wrong places; and when they were carried away they had to be re-constructed, but the final result where the works have been completed has been entirely successful.

A very neat and commodious forest house has been constructed for the use of the guard in charge, and for the accommodation of the officers visiting the works. The total cost of the various works up to the end of 1879 amounted to 92,800 francs, which gives an average cost of about 320 francs per acre; but there being still a few blanks to fill up, and other works to be completed, the final cost of the *reboisement* may be put down at 350 francs per acre. Within the limits of this tract there is a quarry to which a right-of-way has been reserved for the use of the inhabitants of the neighbouring *communes*.

Périmètre of Ouches.

General description.

27. This tract, which adjoins that of Labouret, and in which operations were commenced at a much later period, comprises an area of about 500 acres. In shape it is extremely irregular, the borders being everywhere intersected with cultivation, in which are habitations of various kinds. In India the conservancy in such a tract would be considered unadvisable without the expenditure of enormous sums on fencing, but in the present instance cases of trespass are said to be rare. This is, to a great extent, due to the fact that the neighbouring inhabitants have long been accustomed to forest restrictions, and to the thorough manner in which cases of trespass are, as a general rule, dealt with by the magistrates when they do occur.

Cultural operations.

28. A considerable portion of this tract has been planted up with Austrian pine in the lower parts and with larch at the higher levels. A large nursery has been constructed in the centre, and several smaller temporary nurseries (*pépinières volantes*) in various suitable places. These are generally formed in small scattered patches wherever the ground is suitable, and the plants, being grown on the spot where they are ultimately to be planted, have thus a better chance of succeeding than if grown under more favorable conditions lower down

in the valley. Another advantage of this system is that vegetation being of much slower growth higher up than down below, the plants raised in these localities can be kept for a much longer time in the nurseries until a favourable opportunity presents itself for planting them out; whereas in the case of larch and other pines grown in nurseries situated low down, they become after two or three years too large for planting out at a reasonable cost. Again, the young plants being situated close at hand, advantage can be taken of short periods of weather favorable for planting operations. The size of the nurseries for the *reboisement* works of the Hautes and Basses Alpes is calculated at one acre of nursery to 100 acres of plantation.

Périmètre of Seyne.

General description

29. The next tract visited was that of Seyne, situated about 2½ miles above the village of that name. Its length is about 2½ miles and its average breadth is 1 mile; it occupies the north-east slope of an extensive range of hills. A series of torrents, some of which are of considerable importance, take their rise within its limits and run down to join the Bleone River.

Here, as in most of the tracts hereafter described, the rock is limestone, schist, and sandstone, the lower slopes of the hills being covered with extensive beds of black marl. There are also a few outcrops of nummulitic limestone. The hill sides are generally steep, the upper portions being precipitous. The altitude ranges from 11,330 to 9,330 feet. The rainfall from April to October is about 25 inches, and the snow and winter rains, which have apparently never been measured, would probably increase the total amount to something like 30 or 35 inches, so that the climate is much damper than the greater portion of Northern and Central India. This tract was taken up 17 years ago and is now the entire property of the State. The greater part of the land originally belonged to the neighbouring *communes*, who were, however, induced to sell their rights to the State for 97,000 francs. After the limits of the tract which it was considered necessary to re-forest had been defined, an area of about 792 acres was found to belong to a private proprietor, who strongly objected to sell his right, so that the process of expropriation, based on the principle that in such cases private interest must give way to public welfare, had to be resorted to, and the jury awarded a sum amounting to 22,000 francs, which the proprietor was obliged to accept.

The formalities connected with this operation are of a most complicated and troublesome nature, so that forcible expropriation is only resorted to in cases of urgent necessity. At the time this tract was taken up, it is said to have been completely denuded of all vegetation with the exception of a few stunted Scotch firs and larch, remnants of a once extensive forest. The result of 17 years of conservation has, as regards the increase of natural vegetation, not been at all satisfactory. This may be attributed to the utterly denuded state to which the tract had been reduced, the extreme sterility of the soil, and the severity of the climate. When this tract was taken up, it was found necessary, in satisfaction of an old established right, to leave a sheep path through its centre, to allow access to the higher pastures: the average breadth of this path is about 20 yards, and certain portions of it have been enclosed on both sides by wire fences. There are also three patches of cultivation (*enclaves*) of considerable extent comprised within its limits, which it has not been found expedient to expropriate. The presence of such enclosures, however, in a French forest is not nearly so embarrassing as in an Indian one, for, as the owners are subject to the forest laws, no houses, &c., can be constructed on them without permission. This, unfortunately, is not usually the case in India, where in such patches whole villages sometimes spring up, their presence soon becoming highly embarrassing and ultimately rendering conservancy utterly impracticable.

Cultural operations.

30. Operations having been commenced at a time when the branch of forest science known as *reboisement* was in its infancy, it was thought that the best and most expeditious plan was to sow the whole area broadcast with the seeds of Scotch fir, larch, Austrian pine, &c., and this plan was accordingly at first adopted. In a few places only, where there happened to be tufts of grass to form shelter, and where the covering of turf was not too thick, the young plants (principally larch) succeeded, but in the remainder of the tract the operation was a complete failure. This method has been tried on an

extensive scale elsewhere, and it seems to be the general opinion of the Forest Officers (in this part of France at least) that it is a simple waste of time, money, and seed, and it is only now advocated by those who have never tried it.

Extensive planting operations were then commenced, and have been steadily continued for fifteen or sixteen years, about two-thirds of the whole area having now been completed. The best parts were, of course, operated upon first; and the remaining one-third of the area, consisting of the upper slopes and the most unpromising portions, still remains unfinished. A considerable portion of this latter area has, however, already been planted up once, but the operation failed, the alleged cause being that small one to two year old plants were used, which were too weak to withstand the rigours of the climate at such high altitudes, and strong plants only are to be used in future. With regard to the size of the plants to be employed, it seems to be an accepted principle that the worse the soil and the greater the rigours, either of heat or cold, the larger (within reasonable limits) the plants ought to be.

M. Carrière, the officer in charge, expects to be able eventually to carry the plantations up to the very summits of the mountains: this, with patience and perseverance, he may probably accomplish; but it did not seem, in my opinion, advisable, as the upper portion of the hills is enveloped in snow for seven months in each year; while the rock, consisting of hard limestone, cannot easily be washed away, and the expenditure of funds and energy had much better be confined to works of a more urgent and remunerative nature. The kinds of trees cultivated are Austrian pine and Scotch fir in the lower and central parts; while larch, *pin à Crochets, pin cembro* are planted higher up. Immense quantities of willows are required for these works, and, as they are sometimes difficult to procure in sufficient abundance in the neighbourhood, an extensive willow nursery has been constructed on the *Cône de déjection* of one of the principal torrents. The upper portion of this torrent has been controlled, and some works have been constructed lower down. The cuttings were planted very close together, in long lines about 15 yards apart, rows of large stones being placed immediately above the cuttings so as to afford shelter and prevent them from being uprooted by the frost. These will in a few years form a valuable nursery for the supply of future works.

In addition to the ordinary methods of sowing and planting, the system of cordons has been extensively employed, especially in the black marl hills. This system consists in opening out small cuts, of triangular section, following the contour lines of the slopes. The bottom of the cut has an inward slope, and the depth varies from 8 to 12 inches, according to the hardness of the soil. The distance apart of the cordons depends on the slope of the ground, but, as a rule, they are never less than 3 or 4 yards, and are often as much as 20 yards apart. The bottoms of the cuts are then thickly covered with cuttings or young plants of willow, alder, elm, acacia, &c., laid horizontally close together, their heads protruding about 2 inches. The soil, which is excavated from the next trench, is then thrown down so as to fill up the cut. This operation is commenced at the bottom and continued to the top of the slope. After the cuttings have sprouted and taken a firm hold of the soil, small pines are planted on the excavated portions and in the intermediate spaces between the lines, so that after a few years a section of the *cordons* will present somewhat the appearance shown in Fig 7, Plate II. The whole hillside is generally sown with grasses, which help to consolidate the soil.

Construction of weirs.

31. Innumerable weirs have been completed, and in one ravine alone they have been constructed at distances apart of from 7 to 10 feet for a distance of at least 400 yards. Numerous new works and careful repairs of old *clayonnages* were in progress both at the heads of the ravines and lower down in the valleys; but, as the torrents are not individually of a very formidable nature, the weirs are not of large dimensions.

On the western side there is an extensive area of black marl of the most uninviting nature, which up to the present time has been left untouched, in the hope that it will improve naturally, but, this not being the case, works are about to be commenced, and a series of important *barrages* will be constructed, commencing from below.

The gangs of workmen are admirably organized, each gang consisting of twenty workmen, an overseer, and a boy who brings water, cooks, &c. Huts or

tents are provided for the use of the workmen, who sometimes remain for months on the works, and thus the time and fatigue involved in their daily journey to and from their work is saved.

Buildings and roads.

32. In the centre of this tract, as in nearly all the other tracts which I visited, a neat forest rest-house has been constructed, as well as several seed and other houses at various elevations.

A complete system of roads and paths has also been made. The officer in charge showed me a very useful instrument, called the *Nivean Burel*, which is now extensively used for laying out paths and work of a similar nature, and which has superseded, to a great extent, the somewhat clumsy Éclimètre formerly employed.

Cost.

33. The cost of all the operations in this tract during the seventeen years that works have been in progress has amounted to about 400,000 francs, or about 200 francs an acre for the portion completed.

Périmètre of Riou-Chanal.

General description.

34. The next tract visited was that of Riou-Chanal, situated above Barcelonnette, which, together with an adjoining patch, called Gaudissart, comprises an area of 1,125 acres. The greater portion of this area consists of black marl hills, which are here extremely unstable. Considerable areas are covered with loose rolling boulders. The altitude ranges from 9,000 to 6,330 feet. The rainfall, not including winter snow and rain, is about 30 inches.

The higher part of Riou-Chanal, as well as of the detached portion, has been purchased from the neighbouring *communes*, and has now been under conservancy for about fifteen years. The remainder of the ground still belongs to the *communes*, but its purchase is under negotiation. In fact, it has now been decided to acquire by purchase or otherwise all the tracts under *reboisement*, and owing to the very strict conservancy regulations which must be enforced, and to the very long time which must elapse before any revenue can be obtained, it is to the interest of the *communes* to accept compensation.

The boundaries of this tract, and indeed of all others, seemed to me to be very vaguely defined, no boundary pillars being visible; but the officer in charge assured me that the risks of encroachment are very slight, owing to careful supervision which is exercised, and to the exact manner in which the boundaries have been surveyed.

The greater portion of Riou-Chanal is said to have been formerly utterly denuded of vegetation, and even yet in the portions which have not been planted or sown, the show of vegetation is very meagre. This may, however, be due to the fact that the grazing of cattle (not including sheep and goats) is, as a temporary measure and pending a final settlement, permitted in the lower portions.

Cultural operations.

35. When operations were first commenced, the method of broadcast sowing was adopted, and low down where the conditions were favourable, a certain area is now covered with larch, which is said to be the result of this operation. The method adopted was to sow the seed on the top of the snow, so that it was carried into crevices of the rocks and other suitable places by the melting snow, but, the seed being exposed to view for a considerable time, large quantities of it must, of course, have been eaten by birds.

Since the establishment of nurseries extensive planting operations have been carried on for about ten years, and a considerable area has now been completed, and is well stocked with flourishing plantations of Austrian pine, larch, and other trees. The method of *cordons* which was extensively tried has not, however, succeeded as well as usual, owing probably to the extreme sterility of the soil and to the rigours of the climate, the greater portion of which is covered with snow for at least six months in the year.

Construction of weirs and other works.

36. Some works of importance have been constructed, notably a large masonry weir in one of the main ravines. The weir is about 20 yards in length and from 27 to 33 feet in height, including foundations; above it a series of smaller *barrages* and *clayonnages* are being constructed at regular distances apart, over a distance of about 500 yards. In the smaller valleys numerous rustic weirs, *clayonnages* and *fascinages* have been completed, and the sides of the ravines have been thickly planted with willows, poplars, and other quick-growing trees of allied species. Near the forest house a considerable landslip occurred lately, and it has been found necessary to construct some drainage

works so as to prevent similar accidents. Several large paved drains have been constructed with as few curves as possible, and placed in such a manner as to run off the water rapidly, and thus to prevent the over-saturation of the soil, to which cause the occurrence of similar accidents may generally be attributed.

The cost of all operations up to the present time has amounted to about 167,000 francs, but before the works are completed the total cost will probably attain to double that amount.

Périmètre of Saint Pons.

General description.

37. Situated directly opposite the area last described is the large tract called Saint Pons, within the limits of which the torrent known by the name of Riou-Bourdoux takes its rise. The area under treatment is about 4,000 acres, and its shape is excessively irregular, the boundary making thousands of angles, and the whole area being so thickly interspersed with patches of cultivation and small hamlets that conservancy operations might be thought impracticable.

All the different kinds of torrents described by M. Surell are to be seen here, and the *Cône de déjection* of Riou-Bourdoux alone covers an area of about 450 acres. The altitude ranges from 10,000 to about 3,660 feet, and, as the streams have but a short course it follows that the fall of the torrents is very rapid. On account of the great extent of this tract, the nature of the torrents, and the great sterility of the soil, operations do not seem to be so far advanced as in some of the other places visited, however steady progress is being made, and the works are being rapidly extended.

Cultural operations.

38. Several of the smaller ravines and branches of the main torrent have been controlled, and extensive planting and sowing operations have been completed at their sources. The species planted are larch in the higher portions and Austrian pine with poplar, willows, ash, and other trees on the borders of the torrents. Cordons have been extensively employed, and they have so far succeeded admirably; but, owing to the extreme instability of the soil, their permanent success depends to a great extent on immunity from storms for three or four years; if storms occur they will sweep away the plants and cuttings before they have had time to establish themselves firmly, and the greater part of the work will have to be done again.

Construction of weirs and other works.

39. But by far the most interesting operation is the construction of an immense weir situated at the gorge where the torrent of Riou-Bourdoux issues from the hills. The length of this weir (*barrage*) is about 80 yards, height including foundations 42 feet, and the estimated cost is 130,000 francs, or about £5,200. Rapid progress was being made in its construction at the time of my visit (May 1880), and the whole work was to be completed before the end of last autumn. The immediate effect of the *barrage* is to prevent the further deposit of boulders, gravel, &c., on the *Cône de déjection*, and the annual destruction of about 1¼ miles of the national road, as well as to enable the reclamation of the deposit bed to be commenced in connection with the planting and other operations in the hills above.

A very good system of tramway has been adopted for carrying the necessary materials for erecting the weir. Both rails and ties are constructed of iron, in pieces of from 6 to 9 feet in length, which can be laid down with great expedition and are very durable. This system is now extensively used, in some of the French forests, for the transport of timber.

A considerable portion of the *Cône de déjection* has already been reclaimed by means of the system known as *Colmatage*. This consists in forming a series of small ponds by means of embankments provided with sluices, but if the ponds are small no sluices are made. The muddy water from the torrent is allowed to flow slowly through the ponds, so that after a few years a thick deposit of fine mud is formed above the gravel and boulders, and the soil thus collected is either used for the formation of osier beds or for cultivation. The appearance of the ponds brings to mind the rice cultivation in the outer Himalayas. This system is a very cheap and expeditious means of relaiming the stony deposits of these mountain torrents.

Cost of the works.

40. The cost of the operations in this tract, not including the building of the large barrage, has, up to the present time, amounted to 32,800 francs. An

annual payment of 3,685 francs is made to the *communes* as an indemnity to the neighbouring villages for loss of grazing area.

Périmètre of Faucou.

General description

41. The Faucou tract, which is situated about 2 miles above Barcelonnette, contains the famous torrents of Bourget and Faucou. The accompanying sketch (Fig 8. Plate II) represents the general appearance of these torrents from a distance; it will be observed that the village of Bourget is situated in a very perilous situation. The area under treatment is about 2,180 acres, some parts of which have been conserved for upwards of fifteen years, but the greater portion was only acquired seven or eight years ago. Several rights exist, such as a sheep road, to enable flocks from a distance to reach the higher pastures, and there are also several patches of cultivation within the boundaries. All the available water from the torrents is utilized by the neighbouring villagers for irrigation purposes, and the reclamation of a considerable portion of the *Cône de déjection* has now been accomplished. A considerable part of the deposit bed was cultivated long before the present works were commenced, at a time when the torrent was inactive. It, however, subsequently broke out again with great violence on account, it is said, of the further denudation of the hills, in consequence of an increased demand for fuel, and also on account of increased and unrestricted grazing of animals, which finally reduced the hillsides to a complete state of barrenness.

Gazonnement.

42. At the time this tract was taken up it was arranged that a certain area was to be treated by the turfing process known as *Gazonnement*, the practicability and efficiency of which method was at that time considered beyond doubt. However, subsequent experiments on a large scale, both in this tract and elsewhere, soon proved this to be a delusion, at least in the regions herein treated of.

The following are the reasons on account of which this system is a failure :—

1st.—The grasses which form the thick turf found in the Alpine pastures only grow at very high altitudes, much above the regions occupied by these reboisement works.

2nd.—The roots and stems of the grasses, composing hard turf, form a compact mass like felt, and it is found that the water runs off it very rapidly, and that its powers of absorption are not half so great as those of bushes or forest trees with a good layer of humus and moss under them.

3rd.—At this altitude tufty vegetation, formed of herbaceous plants, takes the place of the Alpine turf; but this generally dries up during the summer, and thus leaves the soil bare and unprotected at the very time when sudden storms are liable to occur.

4th.—In actual practice it is found almost impossible to obtain the necessary seed, owing to the difficulty of collecting it at a reasonable cost, and recourse has been had to sowings of *Sainfoin, Fenasse, &c.* These plants, however, not being suitable to either the soil or climate, have been found to die out after a few years, so that in most cases the experiment has resulted in simple waste of funds, and hence the planting of trees has now been resorted to, compensation being paid to the *communes* for loss of grazing area, or some other arrangement being made with them.

Cultural operations.

43. The natural vegetation consists of Scotch fir, a few *Pin à crochets*, and a good deal of juniper. This latter species, though in every way suited for covering bare hillsides, is never planted, owing, I was informed, to its extremely slow growth. All the methods of planting and sowing already explained have been employed, and complete success has attended the operation, more than half of the area being now covered with flourishing plantations of Austrian pine, with other trees low down, and with larch, *Pin à Crochets*, and others higher up. Considerable plantations of spruce have also been made, but this species has not succeeded well. Poplars have been largely planted, and, especially in the *clayonnages*, extensive use has been made of ash plants, as these are found to grow quicker and take a firmer hold of the soil than the willow.

According to the then accepted theory, operations were at first commenced at the sources of the ravines, with the intention of working downwards, but, for reasons previously explained, it was, after a few years' experience, determined to work both from above and from below.

44. Very extensive engineering operations have been conducted in the main torrents and their branches, and numerous weirs of all kinds and sizes have been constructed. Just above the *Cône de déjection* a very extensive weir, called the Grand Barrage, has been made. Two very interesting models of this may be seen at the Nancy Forest School: the first representing the appearance of the site before the works were commenced, when it must have presented the most hopeless and depressing appearance; the other representing the same place several years after the *barrage* and other works had been completed. At this point a series of landslips formerly occurred, and after several minor works had been tried without success, M. Demontzey, who was then in charge, and who is now the great authority on works of this nature, at last conceived the idea of constructing a strong weir of solid masonry. The length of this weir is about 30 yards, and its height, including 15 feet of foundation, is 87 feet. The thickness at the bottom is 17 feet and that at the top is about 10 feet. The thickness of the structure is excessive, the reason given being that, as this was one of the first *barrages* constructed, it was better to err on the safe side. The total cost was 20,000 francs. Great difficulty was experienced in getting a contractor to undertake the work, so that its expense in proportion to its size is much more than that of other weirs constructed subsequently. Immediately below the *Grand Barrage* there is a second weir of solid masonry, the intervening space being paved with flat stones and lined with retaining walls. Construction of weirs

Above these weirs there are ten others made half of lime masonry and half of rubble. They are of considerable dimensions, and are situated, on an average, 80 to 100 yards apart. Above these works there is a considerable waterfall, after passing which there are 83 rustic weirs and other structures of more or less importance. Between the weirs above described numerous *clayonnages* have been made, and in the space intervening between weirs Nos. 4 and 5 about thirty of these have been constructed. Both sides of the torrent have been confined by means of longitudinal *clayonnages*, and the centre of the bed has been regularly paved with large flat stones, no expense having been spared to make the works as complete and solid as possible. The distance over which the weirs extend is probably about 2 miles. The total cost of the works up to date has amounted to about 454,000 francs, which includes an annual payment of 1,200 francs to a neighbouring *commune* as compensation for loss of grazing area.

45. Here, as in all the *périmètres* which I visited, careful observations of the rainfall are being made, and for this purpose rain gauges have been placed at various elevations, generally at differences of altitude amounting to about 1,500 feet, so that a fair average can be arrived at. Arrangements are made to determine by means of small lamps attached to the gauges the amount of water due to snow. Experiments are also being made in order to determine by means of rough surveys the amount of material carried down by each successive flood in order to ascertain the effects of the *reboisement* works in protecting the hill sides from erosion. The experiments, it may easily be seen, are most difficult to carry out in a satisfactory manner, and the method of proceeding did not seem to me likely to lead to a reliable result. Experiments to determine rain fall and amount of erosion

Périmètre of Les Sanières.

46. A short distance further up the valley lies the tract called Les Sanières, which occupies a well defined basin, the boundaries being less irregular than those of any of the other tracts inspected. The area is 1,090 acres, the altitude ranging between 4,200 and 10,000 feet. The slopes are extremely steep, and in many places precipitous, but the black marl beds are not nearly so extensive as in most of the tracts previously described. This tract has been under conservation for about seventeen years, but planting and other works were only commenced about five years ago. There is very little natural vegetation of any kind, the ground having been reduced to almost complete barrenness owing to excessive grazing before it was taken up; but from tree stumps recently found it seems to have once been covered with a larch forest, even in some of its most unpromising places. General description

No right exists beyond that of the neighbouring *communes* to construct and maintain water-courses for irrigation purposes, and to demand an annual payment of 562 francs as compensation for loss of grazing area.

Cultural operations.

47. The extensive plantations now formed consist principally of Austrian pine and larch, but, owing to the extreme steepness and sterility of the soil, many of them have failed, and if they are to be re-stocked, only large strong plants will be used. Some broadcast sowing is said to have been tried here, but, owing to the extreme barrenness of the soil, the operation proved a complete failure. The most careful precaution is taken with regard to the quality of the seed used. The seeds of the resinous species are generally obtained through contractors from Austria and Germany, where numerous establishments exist for drying and preparing the seed. It is then sent to the central depôt established at Barres, where it is subjected to tests and experiments in order to ascertain its quality, after which, if it is found satisfactory, it is distributed to the various works all over the country.

Construction of weirs

48. Owing to the dry stony nature of the soil, few *clayonnages* or *fascinages* have been constructed, for the willows and other similar species on which the success of these works depends are not found to do well here. Numerous *barrages* have, however, been constructed in the beds of the main torrent and its branches, there being in all fourteen masonry weirs, and about 500 or 600 rustic weirs of more or less importance. But by far the most interesting work to be seen is an extensive stone pavement (*perré*) constructed in the bed of one of the branches of the torrent, near its source. The unstable nature of the hillsides, and the very rapid slope of the torrent bed, would have necessitated the construction of an immense number of *barrages*, and the locality is unsuitable for the employment of *clayonnages*. These considerations led to the construction of the pavement.

The accompanying plan and section, (Figs. 9 and 10, Plate III) will, I trust, give some idea of the nature of this work. The length of the whole work is about 350 yards, and its average breadth is about 20 feet. It is entirely constructed of rubble masonry, with the exception of a lime-built retaining wall at the foot. The pavement is traversed every 5 or 10 yards by crosswalls, which are embedded in the banks at each side, and the foundations of which are about 5 feet 8 inches below the bed of the ravine. These crosswalls permit of the construction of a series of falls, which lessen the gradient of the pavement, and thus enable the work to be constructed on a much steeper slope than would otherwise be possible. These pavements are sometimes constructed on the *Cône de déjection* of torrents, after they approach the period of their extinction, and when it becomes practicable to confine the stream to one well-defined course. The total cost of all the works in this tract up to the present date has amounted to 251,000 francs.

Périmètre of Ste. Marthe.

General description.

49. Having finished the examination of all the principal torrents in the neighbourhood of Barcelonnette, I crossed over the pass of St. Paul and descended through a most interesting and picturesque country to Embrun, situated in the Department of the Huntes Alpes.

The first tract visited in the neighbourhood of this town was that containing the famous torrent of Ste. Marthe. The area subject to treatment is 1,325 acres, out of which there is an area of about 500 acres of natural forest and of land which is to be retained as pasture and subjected to *gazonnement* operations in accordance with sanctioned arrangements. Of the remaining 835 acres the *reboisement* of about one-half has actually been completed. The altitude ranges between 8,740 and 2,933 feet, and the average gradient equals about 1 in 5. The land still belongs to the neighbouring *communes*, which, at the time it was taken up about 17 years ago, offered the most determined resistance to any interference with their grazing rights, and even went the length of murdering two of the forest guards. If this is done in Europe, the determined opposition which forest conservancy meets with in some parts of India is not much to be wondered at.

Cultural operations.

50. In the portions of this tract which have been completed the plan adopted was to cover the ground as fast as possible with any kind of vegetation and extensive plantations were made of willow, alder, and other trees to act as nurses, after which Austrian pine, Scotch fir, larch, &c., have been introduced, and these species will ultimately form the principal crop. About 250 acres of the upper portion have been treated by *gazonnement* with indifferent success, and

as this ground is said to be situated considerably above the region occupied by forest inthis neighbourhood, no attempt at planting is likely to be made. A considerable portion of the planting work has been done by the Forest Guards themselves, who I found busily employed repairing *clayonnages* and other such works. They have made themselves so useful that, as a reward, they have been allowed to plant a small vineyard and cultivate several small patches of land near the forest house.

Construction of weirs and other works

51. In the main ravine and its affluents numerous small weirs and *clayonnages* have been constructed, but none are of great size, as the torrent is a small one. The distance over which these works extend, commencing at the gorge above the *Cône de déjection*, exceeds 2½ miles. The cost has apparently been exceptionally high, and no very clear statement of it was obtained. A considerable portion of the hillside having given indications of slipping, some drainage works are about to be undertaken as soon as the necessary funds are forthcoming.

Result of the operations

52. On examining the *Cône de déjection* of this torrent a remarkable phenomenon is observed, namely, that, since the deposit of boulders, sand and gravel has, by the works undertaken above, been prevented from increasing, the stream, which is no longer charged with solid materials, has hollowed out for itself a distinct bed, which is now from 17 to 33 feet below the old bed of the torrent, and which has well-defined banks, so that all danger of the torrent suddenly changing its course has ceased, and security is thus obtained for the cultivation, which is now rapidly extending on the deposit bed. This is, however, due in the first place to the forest engineering works, and not to the planting and sowing operations, which cannot as yet have had much effect, considering that only about half of the catchment basin is covered.

Périmètre of Les Vachières.

General description

53. The périmètre of the torrent called Les Vachières is directly facing that last described on the opposite side of the River Durance. The area under actual treatment is about 2,408 acres, but the total catchment area of the torrents is said to amount to about 22,500 acres. The boundaries are extremely irregular, the whole area being interspersed with patches of cultivation in which small hamlets are often situated; these must necessarily render conservancy arrangements extremely difficult. The tract comprises the catchment basins of six distinct torrents, the principal one being Les Vachières. The flow of water in this torrent, even during the dry season, is considerable, and its force during moderate floods is formidable. I observed several blocks of rock, each of about 75 cubic feet, which had been carried down last year and deposited on the top of one of the smaller weirs.

No attempt has been made to fence any portion of this tract, and with a boundary so complicated, the absence of cases of trespass struck me as being a strong proof of the peaceful character of the inhabitants of the surrounding villages. Several grazing and other rights exist, which are all defined.

Cultural operations

54. A considerable portion of the area taken up is already covered with patches of larch forest. When planting operations were first commenced the kinds of trees suitable for the black marl soil were apparently little known by the officers in charge, and attempts were made to grow oak, chestnut, and other species, but without success, a few only of the surviving trees, planted about twelve years ago, having attained a height of 3 feet The species now planted is Austrian pine at the lower levels and larch higher up.

Construction of weirs and other works

55. The method of reducing the slopes called *encrétement des berges*, which has been already described, has been adopted with some success.

Some of the *clayonnages*, with their accompanying plantations of alder, willow, &c., have succeeded admirably. The stems and roots of the trees being thickly distributed over the torrent beds, render the carrying along of stones by the water impossible. An attempt was made about ten years ago to control the lower course of the dangerous *Les Vachières* torrent by means of an immense masonry embankment of about 400 yards in length, which cost 50,000 francs. This dyke lasted for six years, but was at last carried away by a sudden flood, owing, it is said, principally to inferior workmanship and faulty curves. The system of weirs now constructed was then decided upon, and a short distance below the old embankment a very substantial *barrage* was constructed about

two years ago at a cost of 70,000 francs. This weir is built of solid masonry, the length being 74 yards, and height, including foundations, 42 feet. The peculiarity of this weir is that the upper surface, instead of being curved where it tends to concentrate the flow of water in the middle, has been constructed nearly level, so that the water is distributed along its whole length. It is protected below the fall by an extensive floor of large stones, as well as by a counter-weir and wing walls, and the blocks forming the upper face are strongly bound together with rivets. The accompanying sketch (Fig. 11, Plate IV) represents the general appearance of this *barrage* and its surroundings. At distances varying from 100 to 200 yards above this weir four additional *barrages* of large size, each estimated to cost about 30,000 francs, are in course of construction. The immediate effect of these works will be to prevent for a time the further deposit of materials on the *Cône de déjection* until the planting operations going on above take effect; they will also prevent the undermining of some extensive areas of cultivation situated in their vicinity. It does not seem to have been decided at present what works are to be constructed above these weirs, but if a series of works of this kind is to be built all the way up the bed of the main torrent for one or two miles, the expenditure will be enormous. In one of the side torrents, called *L'homme mort*, four weirs of considerable size were seen, which had been broken, owing probably to faulty construction, and preparations were being made to re-build them in a more substantial manner. The estimated cost of completing the *reboisement* of this tract, commencing from the current year, is stated to be one million francs.

Périmètre of St. Jean St. Nicolas.

General description.

56. From Embrun I next passed on to Gap, the chief town of the Department of the Hautes Alpes, and there being no works of especial interest going on in the immediate neighbourhood, I was advised by M. Bernard, the Conservator, to visit Pont du Fosse, situated in the valley of the Drac, a branch of the Isère. In the neighbourhood of Pont du Fosse I visited the *périmètre* of St. Jean St. Nicolas, the area of which is about 2,265 acres. Out of this area about 1,000 acres are reserved for grazing purposes, and some *gazonnement* operations have been attempted; the planting of about 250 acres of the remainder has been completed.

The rock is chiefly limestone, schist, and sandstone, with very little black marl; there are also considerable areas covered with loose boulders, which, together with large precipices, reduce the portion available for planting to about 750 acres only. This tract has now been under conservation for about fifteen years, the land still belonging to the neighbouring *communes*. The number of cattle permitted to graze between the 1st June and the 30th September in the portion of this tract set aside for that purpose is strictly defined and regulated according to the estimated capability of the land.

Cultural operations.

57. Notwithstanding the fact that patches of self-sown larch and Scotch fir were found on the ground, a serious mistake seems to have been made at the commencement of the operations in the planting of oak, chestnut, walnut, and such like trees, which were persevered with in spite of repeated failures. Much time and money were thus wasted, until the kinds of trees suitable to the locality were recognized. During my visit to one of the nurseries the officer in charge explained a very successful method of raising larch plants, which are somewhat difficult to rear. This consists in placing rows of large stones on each side of the seed lines after the seeds are sown. By these means the young plants obtain a certain amount of shelter, the stones retaining the moisture, and thus economising irrigation; they also prevent the plants from being uprooted by the action of the frost during winter.

A part of the lower portion of this tract was pointed out to me which, when operations were first commenced, consisted of a mass of rolling stones. This has now, by means of retaining walls, *clayonnages*, *fascinages*, and wholesale planting, been converted into a firm bank thickly covered with a flourishing plantation.

The process known as *Marcottage* has been extensively adopted. This consists in bending down the flexible shoots of alder, willow, and other trees so that a certain portion of them is embedded in the soil, when roots are thrown out, and thus new and independent stems are formed round the parent tree.

This is a sure and expeditious way of covering the ground. Considerable damage has been done to the young plantations by a kind of beetle, and special arrangements were being made for having as many of them destroyed as possible before they had time to deposit their eggs.

The actual cost of planting in this tract with plants two years old has amounted to about 48 francs per acre, the number of plants being about 4,800 per acre, and two plants being usually placed in each pit so as to ensure success.

58. The weirs, *clayonnages*, and other works in the main bed of the torrent are of an unimportant kind, the geological formation being such that very little erosion takes place as compared with that which is encountered in the black marl tracts. The total cost of the operations, including weirs, has amounted to about 70,000 francs, or about 280 francs per acre, which is a high rate, considering that no expensive works have been constructed; but this may be attributed to the errors made at the outset. Construction of weirs.

Fruitière of Chabottes.

59. When in this neighbourhood I visited Chabottes, one of the *Fruitières* now common in this part of France; it is situated on the road from Gap to Pont du Fosse. It is owned by a Society of the leading inhabitants of the neighbouring villages, formed under the auspices of the Forest Administration, in order to favour the keeping of cows in preference to goats and sheep, which, as every one is aware, are much more destructive to forest vegetation than cows. The Forest Department hopes, by the encouragement given, to stimulate the formation of numerous private societies similar to those that have existed in Switzerland and elsewhere for many years. The buildings have been constructed at the expense of the State and have cost about 15,000 francs. They consist of a large dairy, and another room containing the churns, cheese-presses, and other implements, all on the most improved principles. There is also an extensive cellar for storing the cheese. About 130 cows belong to this society; the milk being brought from the farms in the neighbourhood daily, when it is carefully weighed and a receipt is given for it by the person in charge. Butter and cheese, but principally the latter, are manufactured on a large scale, and consequently at a much less cost than if each individual manufactured his own share at home; and they are afterwards sold, the proceeds being divided among the different members of the society in proportion to the quantity of milk supplied by each. The profit is said to amount to about 30 or 40 francs per annum on the produce of each cow. No arrangements are made for growing fodder for the cattle, as seems to have been understood from previous descriptions which have reached India, the name *fruitière* being somewhat misleading.

The main object of the Forest Department is to secure the substitution of cows for sheep and goats, but no guarantee seems to exist regarding the suppression of the goats and sheep as no enumeration of them is made. It is said that a limited amount of winter fodder being available, the inhabitants could not afford to increase the number of cows, and at the same time to keep the number of sheep and goats which they formerly possessed. This is true; but it must be borne in mind that there is apparently nothing to prevent the inhabitants from forming combined flocks, which could easily be driven to the low-lying plains at the mouth of the Rhone during the winter months.

With regard to the general practicability of this scheme, the nature of the grazing-grounds in the vicinity of the *fruitière* must be considered. In many cases it happens that the ground is of such a rocky and precipitous nature that it is quite impossible for any animals, except goats and sheep, to find footing; when this is the case, the idea of substituting cows for goats and sheep must be abandoned. It also frequently happens in these poor mountainous countries that considerable numbers of the inhabitants can only afford to keep two or three sheep or goats, and that the maintenance of a cow would be altogether beyond their means. The scheme is, however, on the whole, a good one.

Fruitière of Orcières.

60. There is another extensive *fruitière* at Orcières in the same neighbourhood: the area is 15,000 acres, of which 5,000 acres are set aside for grazing purposes under efficient supervision. There are two sets of buildings, the

one low down for winter use, and the other high up in the summer pasture grounds. Time did not admit of my visiting this extensive tract, where forest works have not yet been commenced on a regular system.

Mount Faron.

General description

61. While in the south of France I did not lose the opportunity of visiting the famous Mount Faron, situated above the town of Toulon, and regarding the *reboisement* of which much has lately been written. Full details regarding the progress of this interesting work are to be found in the Indian Forest Conference Report of 1874, but a few particulars of my own observations may be interesting; but, as I was unfortunately unable to meet with any one thoroughly well acquainted with the progress of the works, allowance must be made for the incompleteness of the information I was able to obtain.

Mount Faron forms the central part of a range of hills of magnesian limestone, stretching along to the north of Toulon. From the backward condition of the vegetation, it even now presents a very desolate and forbidding appearance; and it struck me that it was of quite as dry and barren a nature as many of the arid hills of Rajputana or of the Punjab. The essential difference, however, between this mountain and the black marl hills of the Hautes and Basses Alpes already described, is that the hard limestone of which it is composed cannot be disintegrated, and thus form dangerous mud and boulder torrents, even though the hills are denuded of vegetation. Although considerable damage to the cultivation has resulted from the felling of the forests on the slopes of this mountain, it is, I think, rather an exaggeration to say that the harbour roads were obstructed by the *débris*, or that the mountain consists of a mass of rolling stones, as some descriptions of the locality would lead one to believe.

The area submitted to *reboisement* is 913 acres, the whole of which belongs to the Municipality of Toulon, but, as the mountain forms one of the principal points in the line of defence of Toulon, it is subject to certain military rules and regulations, and the works have, recently at all events, been under the immediate superintendence of the military authorities. The annual rainfall is about 28·3 inches, which is much above the average found in most of the drier parts of India, where works of a similar nature have been undertaken, and the proximity of the sea must necessarily render the atmosphere extremly moist. Judging from some patches of the ancient forest and from solitary trees still standing, the natural vegetation seems to have consisted principally of Scotch fir and Maritime pine, and the sight of these trees was, of course, very encouraging to the officers who commenced the work, as their presence demonstrated that the *reboisement* of the hill was by no means an impossibility. The undergrowth consists principally of broom, juniper, brambles, *Quercus laccifera*, and *Ilex*; but owing to the fact that seeds of all kinds of plants were sown when the operations were first commenced, many shrubs and bushes are now to be seen which are not indigenous. This tract has now been subject to the strictest conservancy for upwards of twenty-seven years, and, as the portion belonging to the town of Toulon had been reduced to a complete state of barrenness, and was, therefore, useless as a grazing-ground, there could not have been much trouble in inducing the neighbouring inhabitants to give up their grazing rights. But it is said that they had abandoned the keeping of large flocks for many years previously, and confined themselves to the cultivation of vines, olives, and figs, which was found to be a much more lucrative employment. But the difficulties to be encountered in some parts of India, where grazing has to be excluded from forests, the population near which make their livelihood chiefly by keeping large flocks of sheep and goats, are immensely greater than those here experienced; and no comparison is admissible between the attempt to exclude cattle from Mount Faron and similar attempts in India, especially as in the latter country the neighbouring inhabitants are, as a rule, incapable of appreciating anything beyond the present loss of their grazing area. I must confess that I was rather disappointed with the show of natural vegetation represented by twenty-seven years of conservancy, and I could point out several tracts in India which were probably equally barren when first taken in hand, and which, notwithstanding the great difficulty of keeping out cattle, exhibit a much better natural growth even after four or five years' conservation.

62. The method generally adopted for effecting the *reboisement* of this tract has been by means of sowing seed in pits dug from 2 feet 8 inches to 3 feet 4 inches in depth, all the good soil being afterwards thrown in. This usually left the pits about 1 foot 8 inches deep, thus giving the young plants a certain amount of shelter during their early growth. Owing to the very hard rocky nature of the soil, which necessitated the digging, or rather quarrying out, of the pits in places where there was a probability of finding fissures in the rock, the pits are very irregularly distributed over the ground; but, as a rule, they are from 3 to 5 yards apart. As the sowings often failed, and seeds had to be sown over and over again, most of the pits are now filled with strong plants of maritime pine, Chêne vert (*Q. Ilex*), and other trees of all ages. About 5 per cent. of the pits are empty, the rock having proved too compact to allow the roots of the plants to penetrate it. Some of the older trees are now from 15 to 20 feet high, and seem to be in a most flourishing condition, the ground underneath them being well covered with humus. Nearly the whole area has now been completed, with the exception of the parts situated in the immediate neighbourhood of the fortifications, and of the side nearest to Toulon, where the ground is for the most part precipitous. Resinous trees seem to have been originally propagated with a view to their being eventually replaced by deciduous trees suitable for coppicing whenever it should become necessary to clear portions of the forest for military purposes; but this idea has been found altogether impracticable of execution, as it appears that resinous trees only will grow on the hard limestone soil which is here found. All attempts at the propagation of larch, cedar, Eucalyptus, and such like trees have failed. Planting would undoubtedly have succeeded better than sowing, but sowing was found to answer, and it is much less expensive than planting. Cultural operations.

The expenditure on these works is said to have amounted to about 100 francs per acre, which is much less than the cost of the *reboisement* works previously described; but it must be remembered that at Mount Faron no masonry weirs or other works of a costly nature have been constructed. The *reboisement* of Mount Faron has, so far as it has progressed, been an undoubted success, and it has apparently been executed at a very moderate cost; but here the rainfall and climate are much more favourable than in India, and experienced supervision and skilled labour are available. It may, however, be argued that in India there are some species of trees capable of withstanding long droughts and excessive heat for a much longer period than any European species. This must be admitted; but, on the whole, I think that the conditions are decidedly more favourable at Mount Faron than in India, even though they are, perhaps, as unfavourable as will be found in any part of France.

CHAPTER III.

Conclusion.

63. In conclusion, I beg to add a few remarks by way of comparison between the *reboisement* works undertaken in France and works of a similar nature attempted in India. In the first place, the soil of most of the tracts which I visited in the south of France is as bad as that of any of the hills situated in the drier parts of India; but the rainfall, which varies from 28 to about 35 inches, is much more than the average rainfall of the arid zone of India, and the heavy dews, coupled with the proximity of the sea, which is not more than 100 to 150 miles distant, add to the moisture of the climate.

As regards the extensive employment of *clayonnages*, *fascinages*, and such like works, which have contributed so extensively to the results of the undertaking, their successful application depends on the capacity of willow and cuttings of similar species to take root easily; and only in very rare cases, such as on the borders of rivers and other moist places, can this be expected in India, where white-ants and rapid decay generally render the use of wood in any shape utterly impracticable.

Reboisement operations in India are therefore undertaken at a considerable disadvantage as compared with works of a similar nature in France, because the construction of dry stone weirs or dry earthen bunds is alone practicable, and they are not always so suitable, and they are certainly much more costly and difficult

to build than structures in which wood can be used. The careful and intelligent supervision exercised by the numerous subordinates, who are so different from the ignorant and careless people we are obliged to employ in India, has contributed in a marked degree to the success of the works undertaken in France. These men are usually trustworthy, and their evidence is generally accepted by the magistrates in the prosecution of persons charged with forest offences, so that the difficulty of finding witnesses who are not Government employés, which so often embarrasses Forest Officers in India, is not experienced in France, and the consequence is that very few cases of trespass or other forest offences have to be dealt with. When such offences are proved, they are generally punished severely by the magistrates, and the people have now become accustomed to the restrictions of forest laws. Under these circumstances, complete conservancy, which is, of course, the most important element in the success of these works, may be said to be attained ; and this fact alone makes the success of such undertakings much more probable than that of similar operations in India, where the conservancy arrangements, even under the most favourable circumstances, are very faulty, owing, in a great measure, to the immense areas which Forest Officers are generally called upon to supervise, and to the want of trustworthy and intelligent subordinates.

Again, the officers in charge of these works are rarely transferred, and some of those I met had devoted their whole attention to the treatment of a single tract for as much as ten or twelve years ; and they have thus been enabled to take full advantage of the local experience they have gained, while they have not, as a rule, been burdened with the multifarious duties which have to be performed by Indian Forest Officers.

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